Thick superconducting films for high current coated conductors

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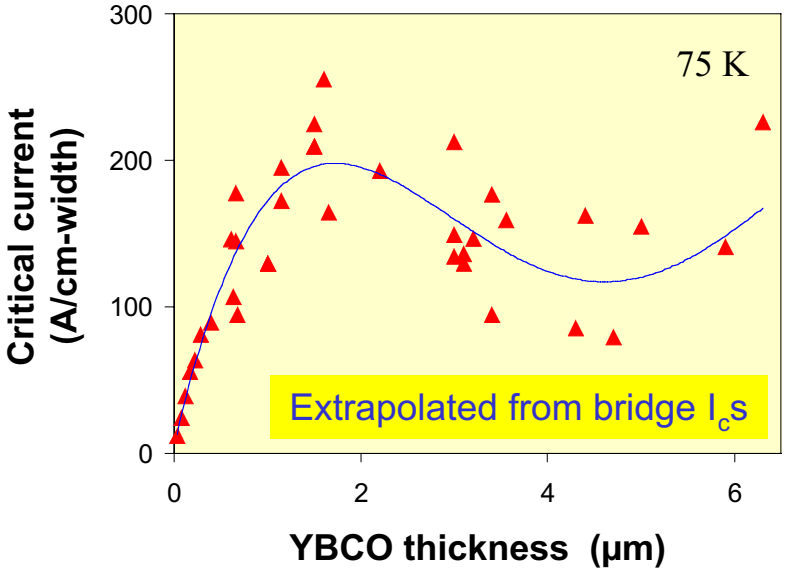
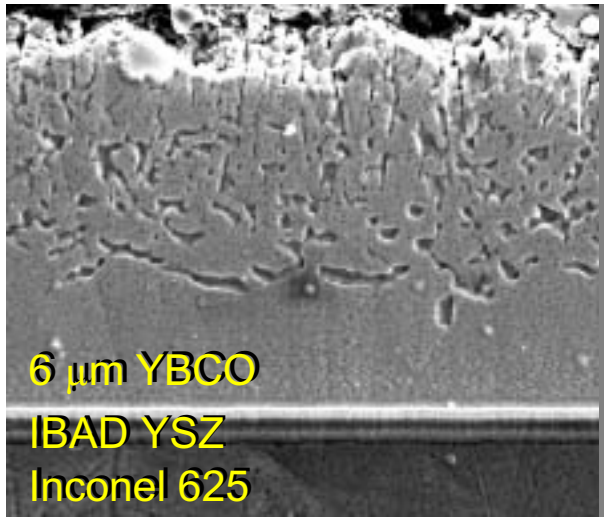
Development of high current coated conductors requires an improvement over "standard" YBCO

Laser-deposited YBCO on CeO_2 or Y_2O_3 -buffered IBAD YSZ on Ni-alloy

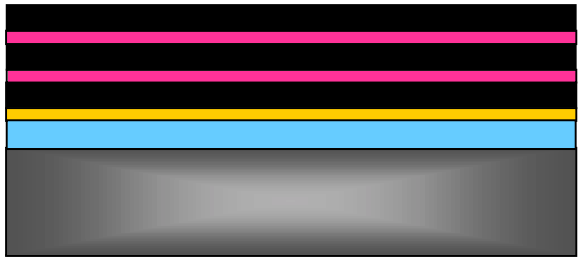
The critical current of YBCO stops increasing beyond a thickness of ~ 2 μm ...

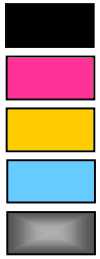


… because of roughness - induced porosity in the growing film



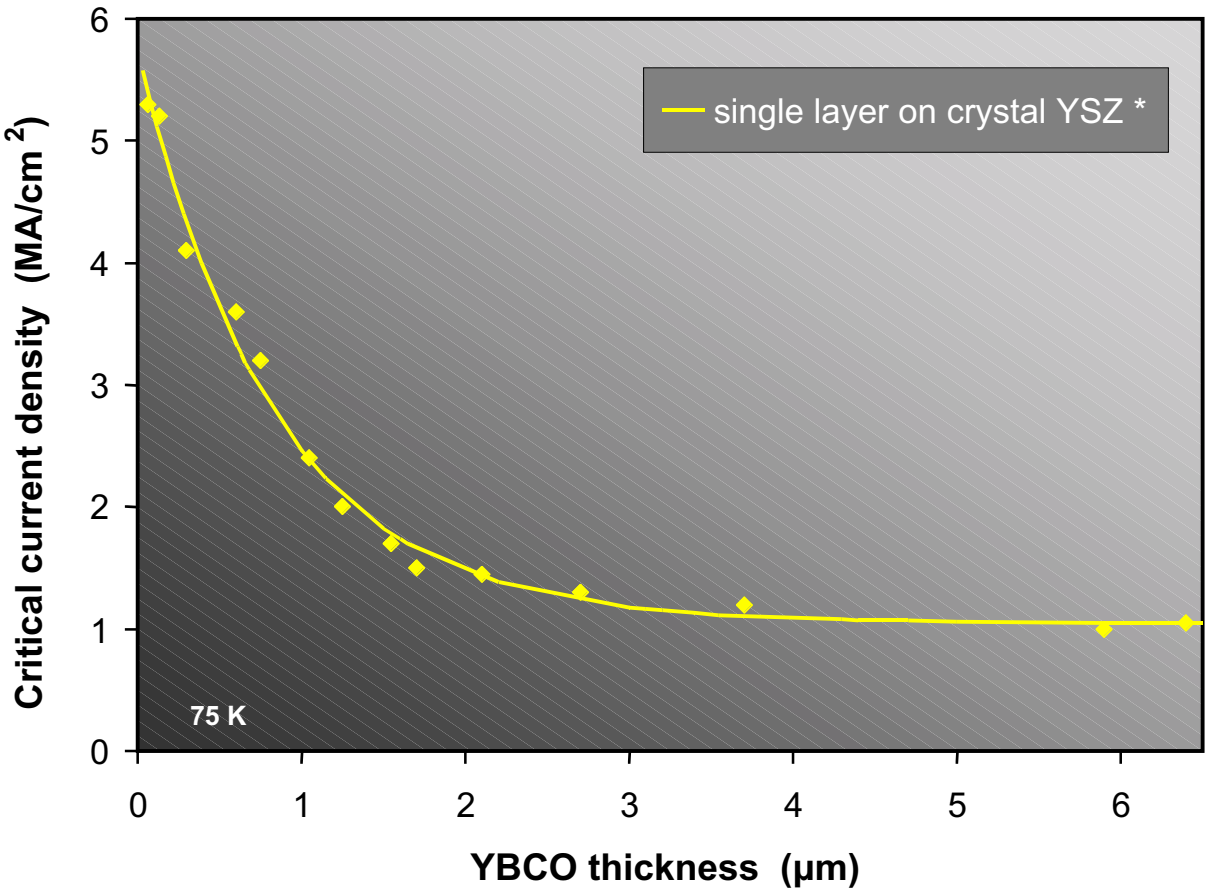
One such improvement utilizes ~ 1 μm YBCO layers separated by thin (~200 nm) layers of $SmBa_2Cu_3O_{7-\delta}$





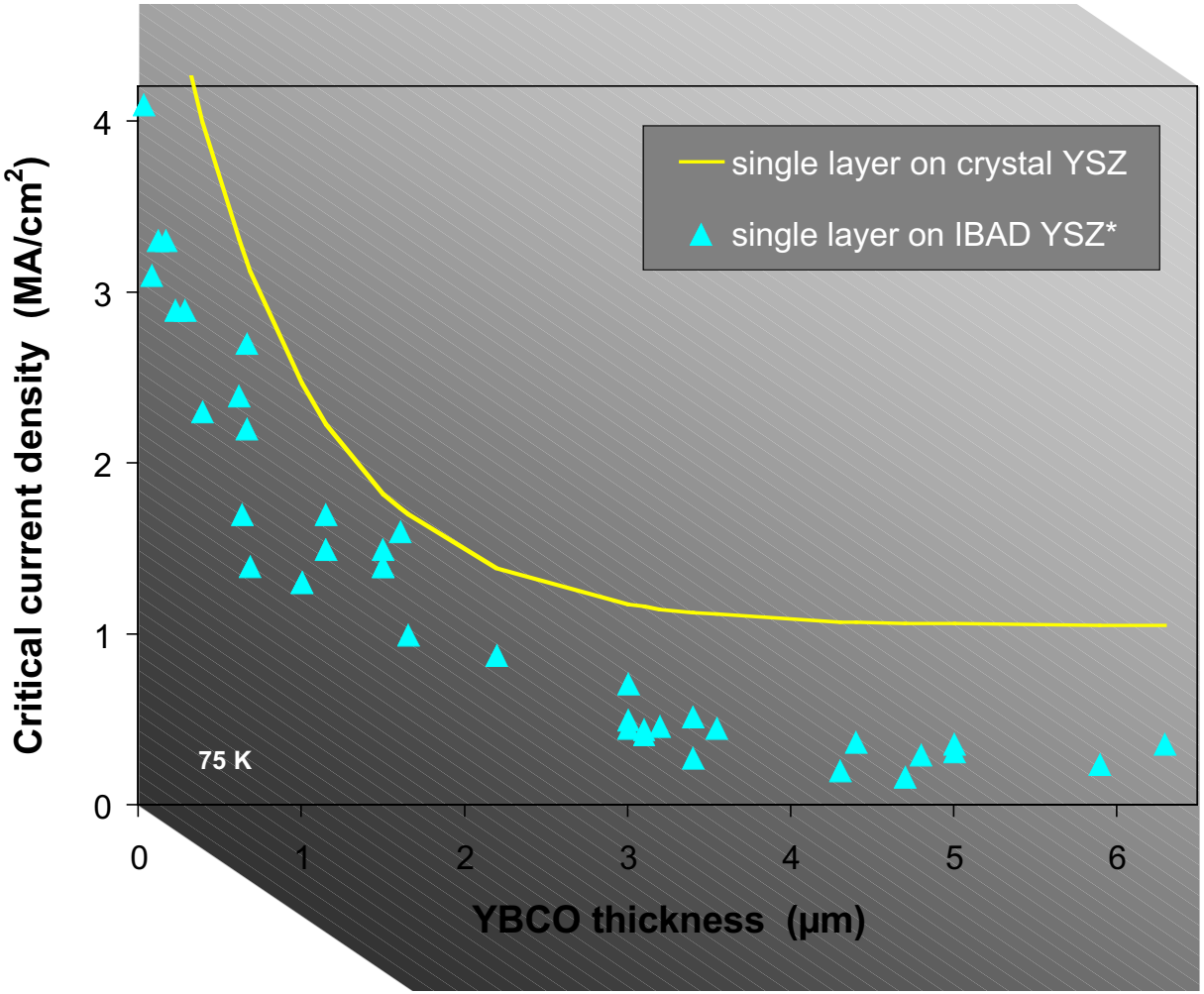
- A multilayer architecture combines the intrinsically smooth growth habit of $SmBa_2Cu_3O_{7-\delta}$ with the high J_c of YBCO
- Such films are dense up to at least 5 μm, and carry current throughout the entire superconductor thickness
- In bridges, I_c levels (75 K) of 400 A/cm-width are achieved routinely, with some samples reaching over 500 A/cm
- On cm-wide, continuously-processed tape, an I_c of 335 A has been measured, and a 225 A meter has been produced (2 μm thick, Y-Sm-Y multilayers)

The high J_c values typical of thin YBCO cannot be maintained in thick films (e.g. 5 MA/cm^2 at 5 μm)



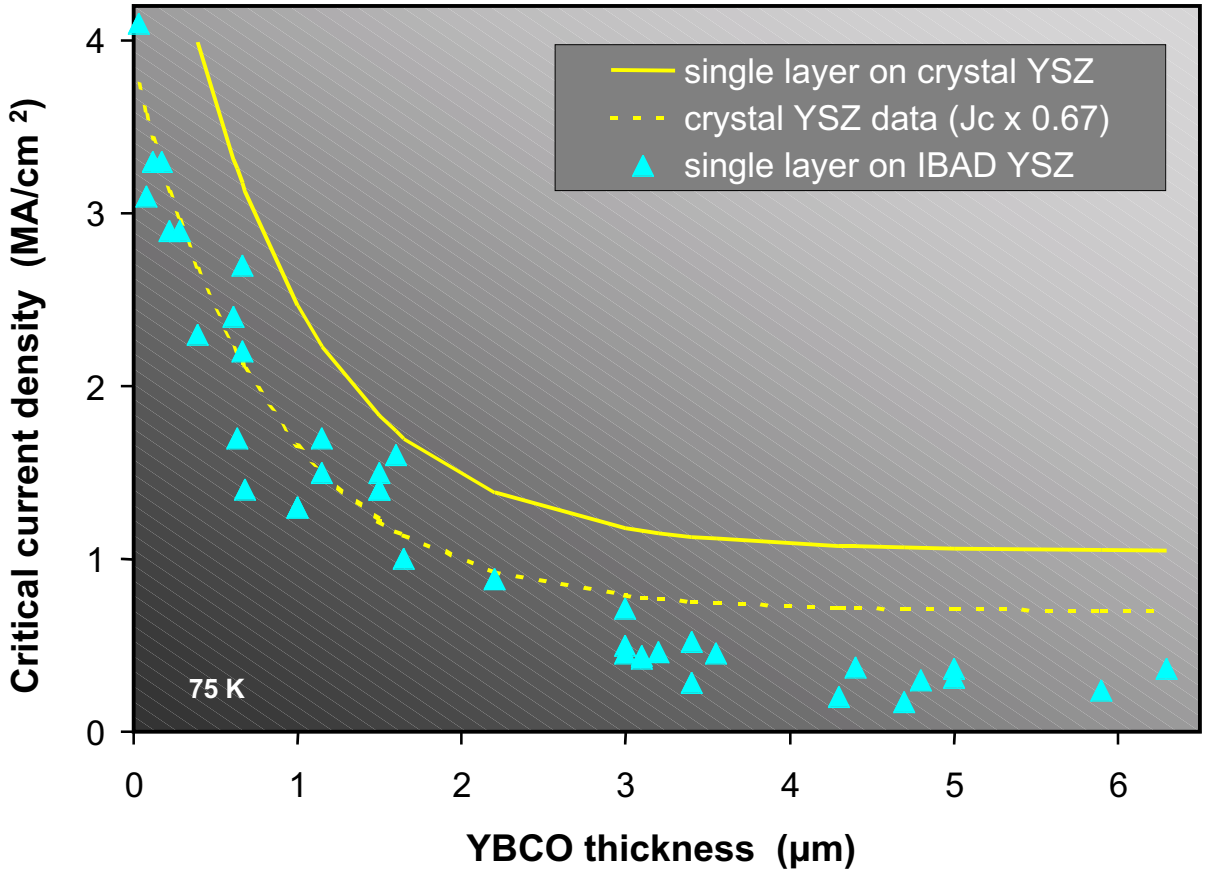
* Appl. Phys. Lett. **63**, 1848 (1993)

A similar $J_c(t)$ trend is observed for IBAD YSZ on metal substrates

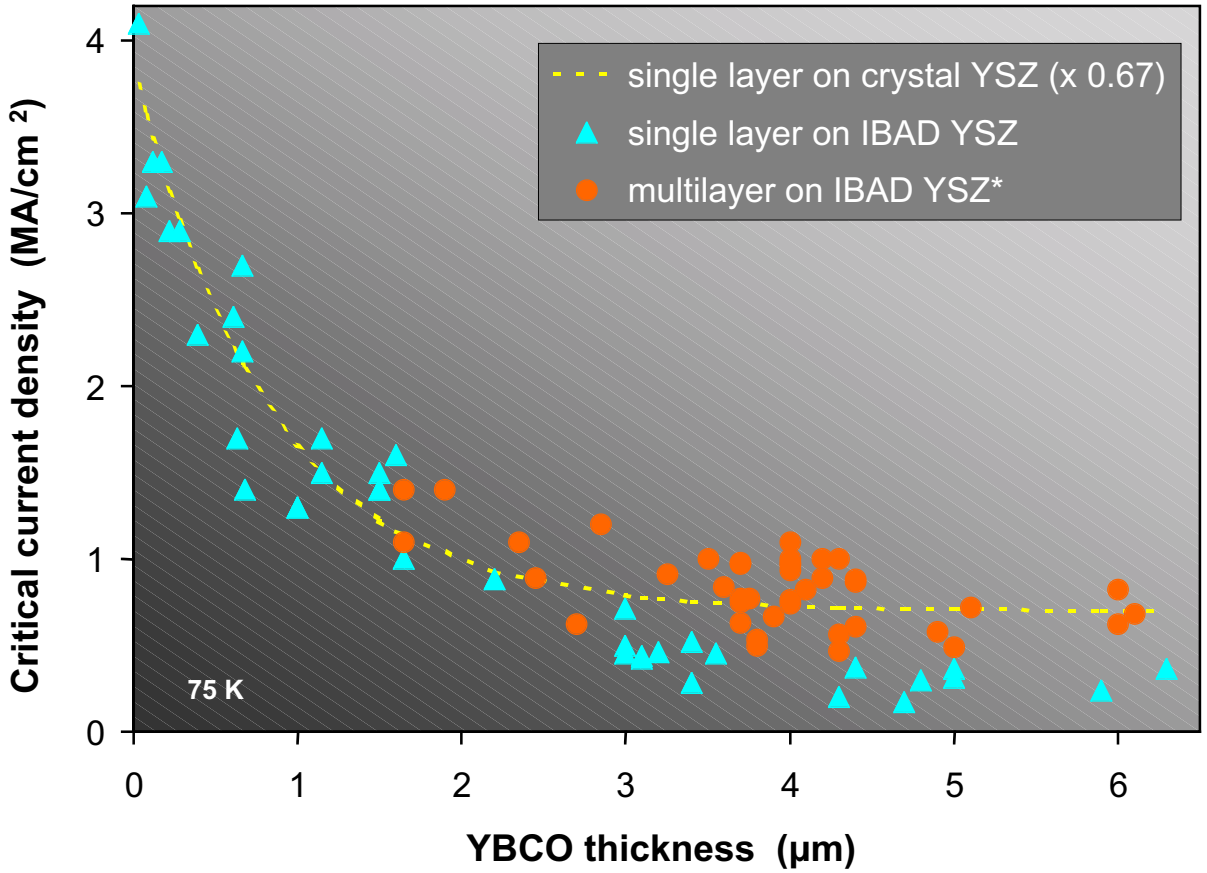


* Appl. Phys. Lett. **75**, 3692 (1999)

J_cs on metal substrates are about 2/3 of those for single crystal substrates … at least for YBCO thickness < 2 μm

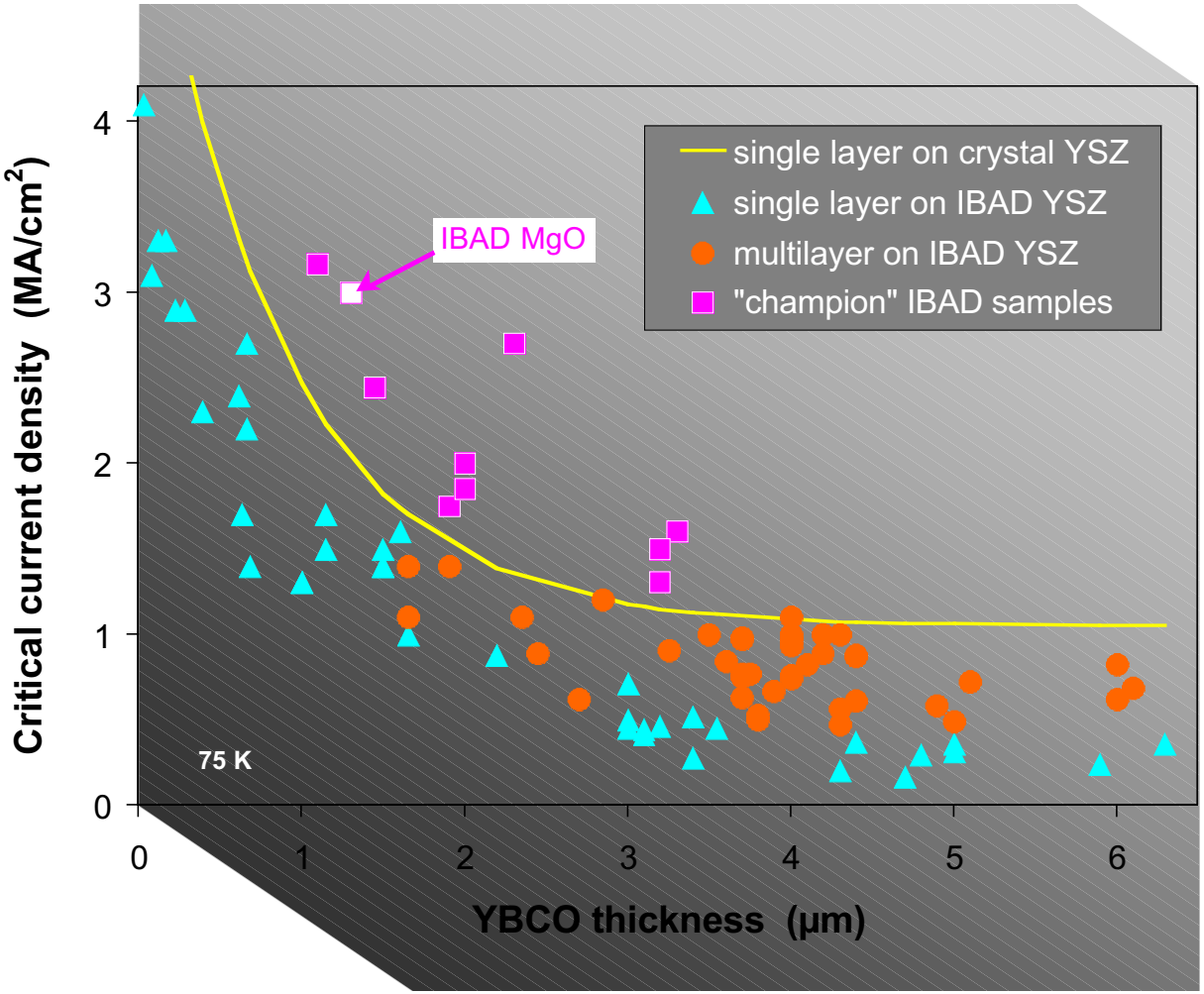


Multilayers restore IBAD-based J_cs to the single crystal trend, but do not alter the trend



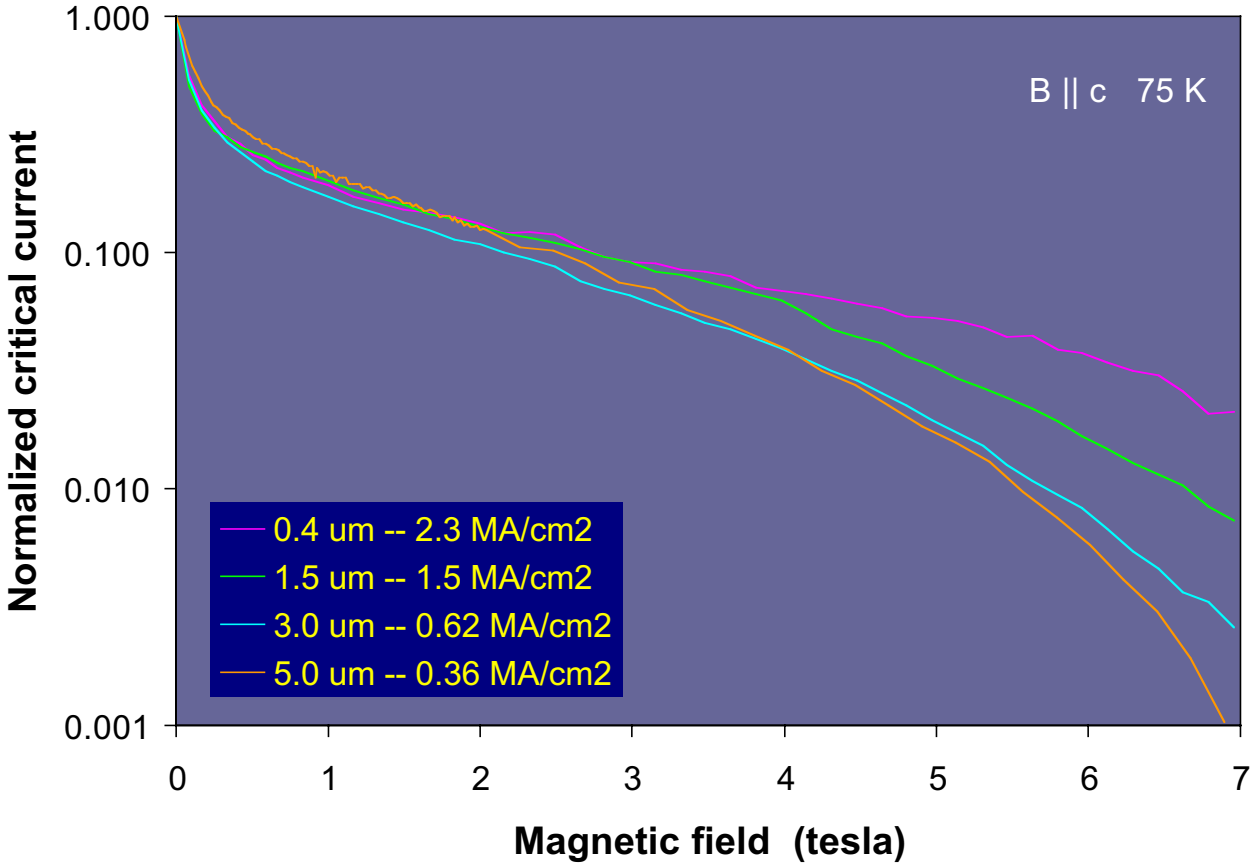
* Appl. Phys. Lett. **80**, 1601 (2002)

Several recent samples have exhibited “trend-breaking” potential

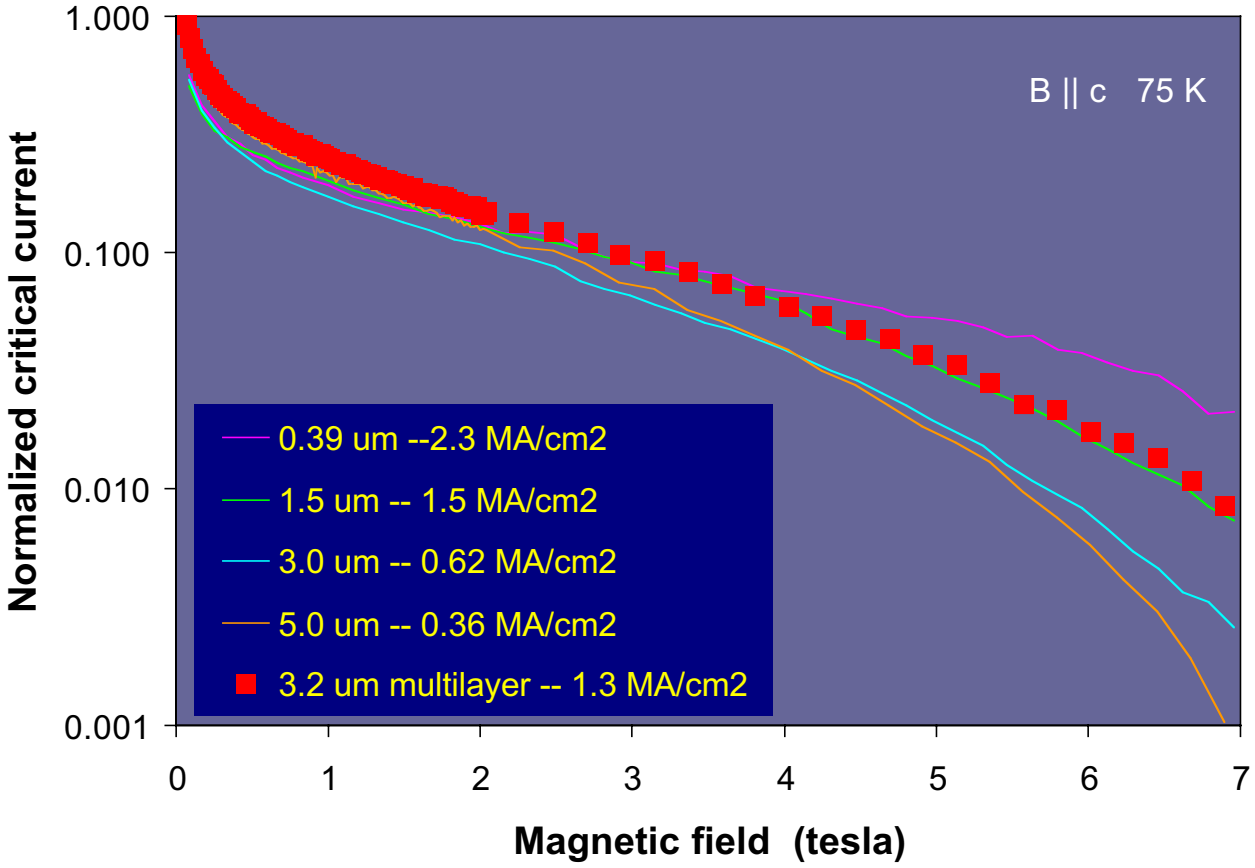


$J_c(t)$ is relatively field-independent up to ~ 4 tesla; in higher field, thick films fall off more rapidly than thin ones

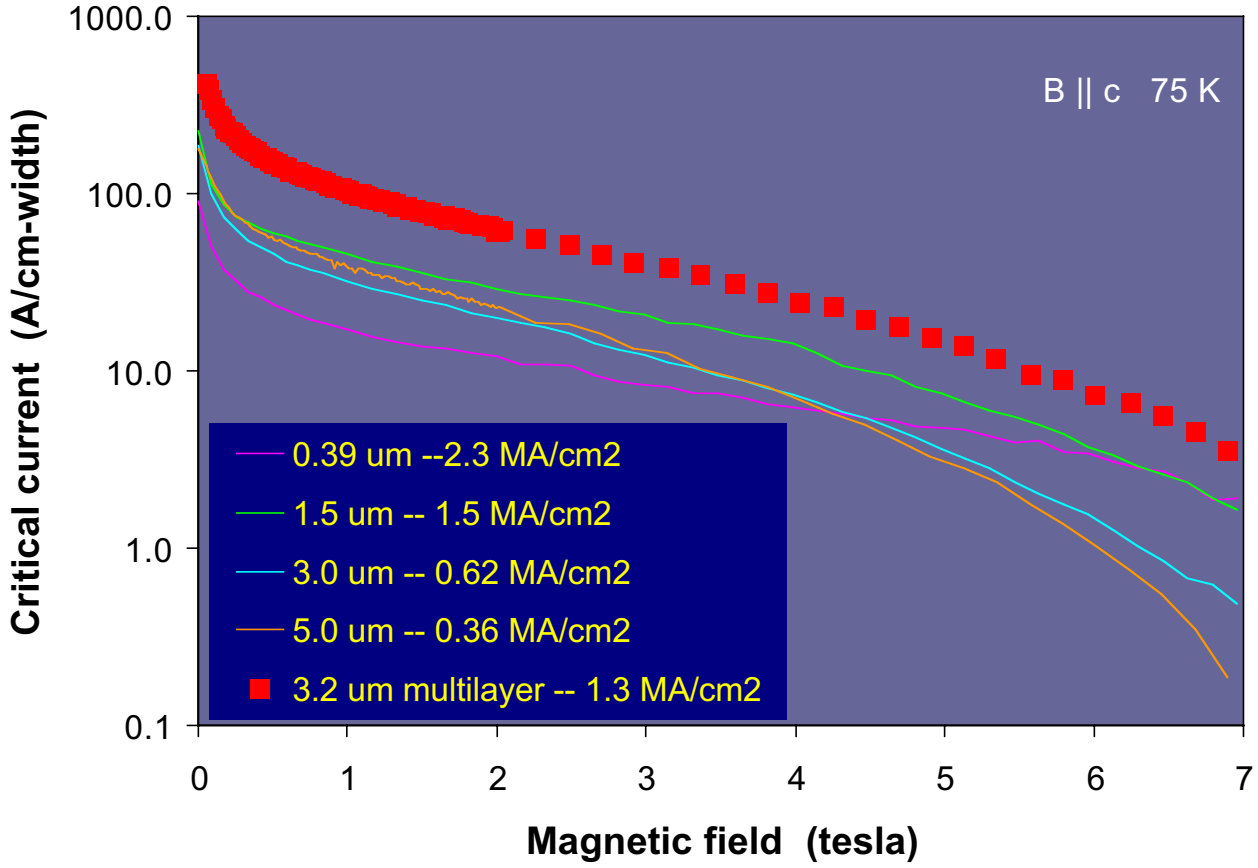
Laser-deposited YBCO on CeO_2-buffered IBAD YSZ



Field dependence of a thick multilayer is similar to that of a thinner film with comparable J_c ...



… resulting in greatly improved performance on an absolute scale



TEM cross-section reveals that the YBCO grain structure is unaltered by the presence of Sm123 interlayers

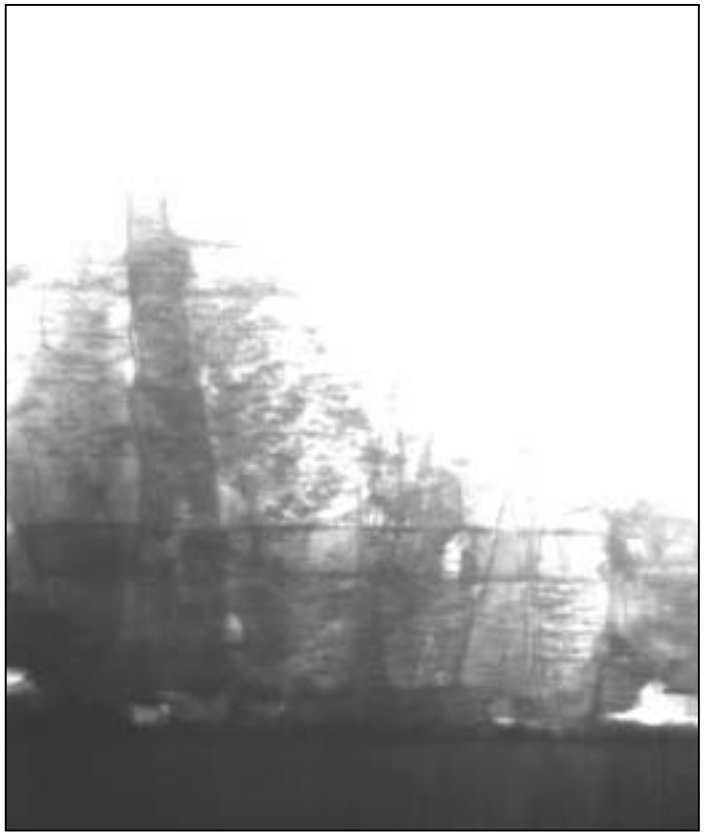
1.1 μm YBCO

0.2 μm Sm-123

1.1 μm YBCO

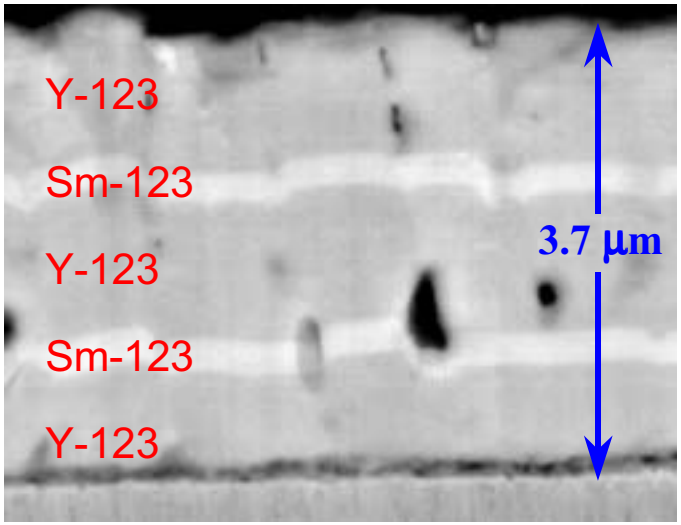
0.2 μm Sm-123

1.1 μm YBCO

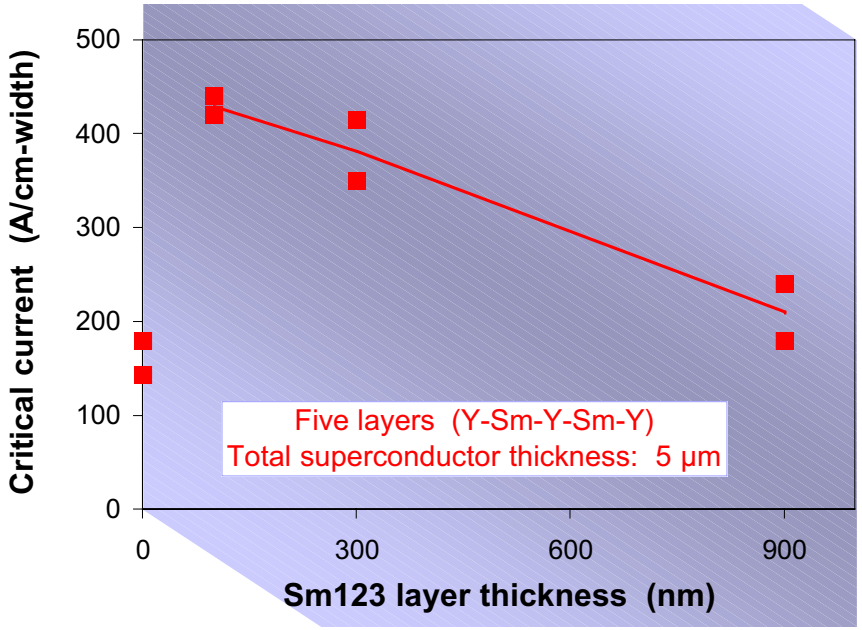


Sm123 interlayers do not planarize the YBCO surfaces as originally suspected

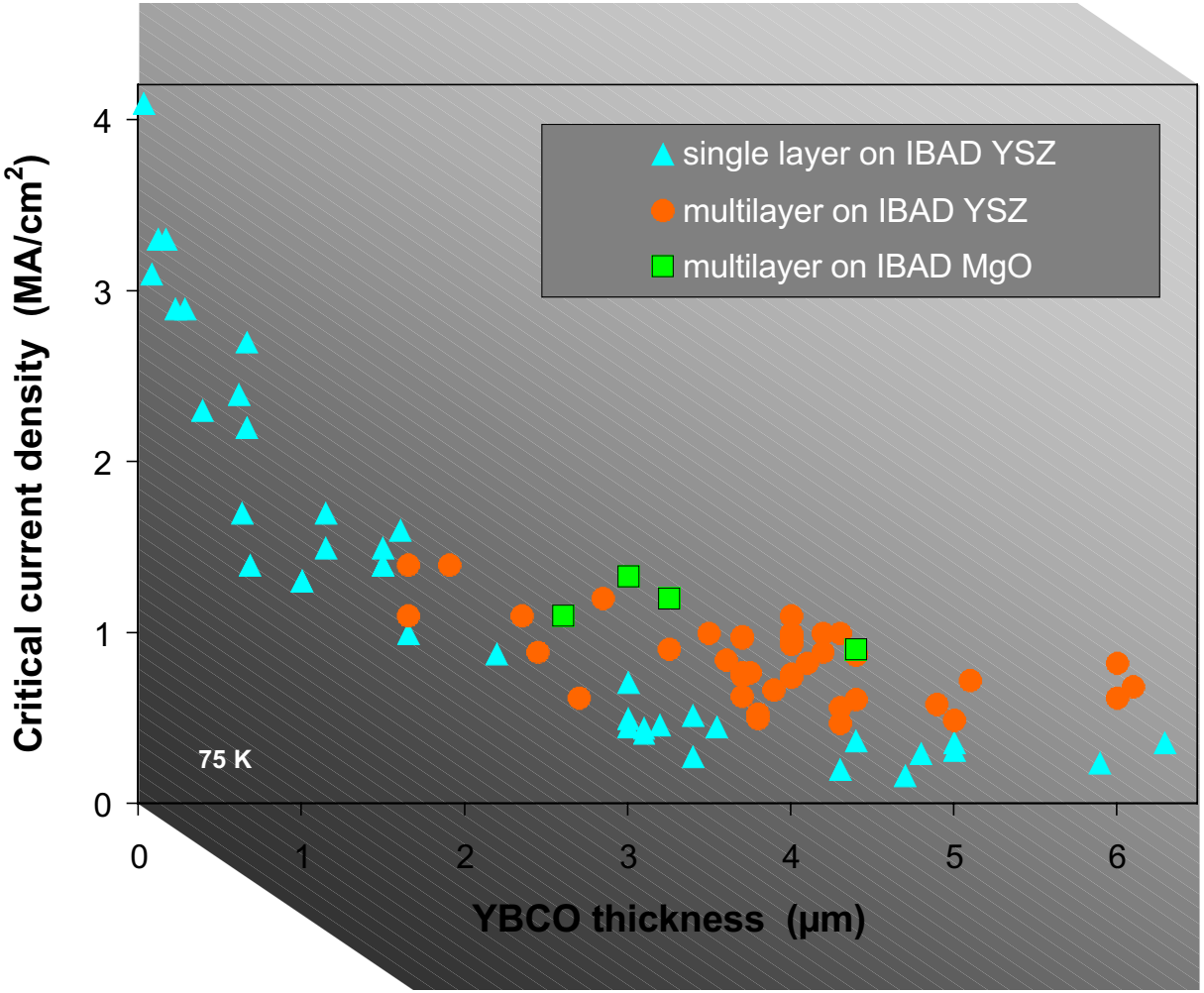
Interlayers do not smooth the YBCO surface, but appear to inhibit cumulative roughening. Reduced porosity above 2 μm is the result.



This is consistent with our previous observation that thinner Sm123 results in higher I_c (since the planarization hypothesis should favor thicker layers)



High current thick films have also been successfully deposited on IBAD MgO



Conclusions

© YBCO/Sm123 multilayers enable the growth of thicker films with high J_c by reducing porosity above ~ 2 μm.

© The mechanism for porosity reduction does not involve planarization of the YBCO surface by Sm123, or alteration of the superconductor grain structure; however …

© The Sm123 layers do inhibit the cumulative roughening process that leads to current-blocking porosity.

© In addition to improvements at self-field, multilayers yield higher I_c than YBCO single-layer films in an external magnetic field.

© Multilayers of 3 – 4 μm thickness on IBAD YSZ or IBAD MgO have $J_c > 1$ MA/cm^2.